ORIGINAL ARTICLE

The Influence of Bedroom Environment on Sensitization and Allergic Symptoms in Schoolchildren

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Abstract

Background: Bedroom conditions have been associated with an increased risk of allergy.
Objective: The aim of this study was to evaluate the relationship between sleeping environment and sensitization and allergic symptoms in schoolchildren.
Methods: A cross-sectional study, the Aalst Allergy Study, was performed in an unbiased community population of 2021 Belgian schoolchildren, aged 3.4 to 14.8 years. Skin prick testing was performed with the most common aeroallergens and bedroom conditions (presence of stuffed toys, type of flooring, and bedding material) were documented through a parental questionnaire.
Results: The presence of stuffed toys in the bedroom was associated with a lower prevalence of overall sensitization and a lower prevalence of conjunctivitis and allergic respiratory symptoms. That effect was almost exclusively present in children with a positive family history of atopy and was more pronounced as the number of stuffed toys increased. A significantly lower prevalence of overall sensitization, sensitization to house dust mite, and wheezing was documented in children with nonsynthetic bedding materials. That effect was exclusive to children with a positive family history of atopy. Type of flooring was not associated with sensitization or allergic symptoms.
Conclusion: Our data suggest that bedroom exposure to stuffed toys and nonsynthetic bedding materials may have a protective effect against sensitization and allergic symptoms in genetically predisposed children. Confirmation of these findings will require further prospective studies that include measurement of levels of mite allergens and endotoxins and assessment of the time, degree, and duration of the exposure.

Key words: Sensitization. Skin prick test. Aalst Allergy Study. Stuffed toys. Bedroom. Allergen exposure. Children.

Resumen

Antecedentes: Las condiciones del dormitorio se han asociado con un aumento del riesgo de padecer alergia.
Objetivo: El objetivo del estudio fue evaluar la relación entre el entorno en que duermen y la sensibilización y síntomas alérgicos entre escolares.
Métodos: Se llevó a cabo un estudio transversal, el Estudio de la Alergia de Aalst, en una población de la comunidad sin sesgo de 2.021 escolares belgas de entre 3,4 y 14,8 años de edad. Las pruebas cutáneas se realizaron con los aeroalérgenos más comunes y se documentaron las condiciones de los dormitorios (presencia de peluches, tipo de suelo y ropa de cama) mediante una encuesta a los padres.
Resultados: La presencia de peluches en la habitación se asoció con una menor prevalencia de sensibilización en general, así como con una menor prevalencia de síntomas respiratorios alérgicos y conjuntivitis. Este efecto ocurría casi exclusivamente en niños con un historial familiar positivo de atopia y fue más pronunciado cuanto mayor era el número de peluches. En los niños con ropa de cama no sintética, se observó una prevalencia significativamente inferior de la sensibilización en general, a los ácaros del polvo doméstico y de sibilancias. Este efecto fue exclusivo en los niños con un historial familiar positivo de atopia. El tipo de suelo no se asoció con síntomas alérgicos ni de sensibilización.
Conclusión: Nuestros datos parecen indicar que la exposición en el dormitorio a juguetes de peluche y a ropa de cama no sintética puede tener un efecto protector contra los síntomas alérgicos y la sensibilización en los niños genéticamente predispuestos. La confirmación de estos hallazgos requerirá la realización de más estudios clínicos para medir los niveles de alérgenos de ácaros y endotoxinas y para valorar el momento, grado y duración de la exposición.

Palabras clave: Sensibilización. Prueba cutánea. Estudio de la Alergia de Aalst. Juguetes de peluche. Dormitorio. Exposición a alérgenos. Niños.

Introduction

Over the last 30 to 40 years there has been a rise in the incidence and prevalence of atopic disorders [1-3]. A possible explanation for this evolution is the so-called hygiene hypothesis, which was first formulated in 1989 by David Strachan [4]. He reported an inverse relationship between family size and development of allergic disease and proposed that a lower incidence of infections in early childhood, acquired prenatally or transmitted by unhygienic contacts with older siblings, could be the cause of the rise in allergic diseases. Subsequently the concept evolved into the broader notion that declining microbial exposure is a major causative factor in the increasing incidence of atopy seen in recent years. However, the mechanism by which reduced exposure to pathogenic or nonpathogenic microbes results in a higher prevalence of allergic disease is still not clear [5-7]. Most recently, Strachan's hypothesis has been further strengthened by the trend not only towards smaller family sizes but also towards cleaner homes [8].

On average, people spend a third of their life in the bedroom. Studies have shown that, of all the rooms in the home, bedrooms often contain the most house dust mites (HDM) [9], and clearly, avoidance of this allergen is the most effective way to relieve symptoms in HDM-sensitized patients [10,11]. These preventive measures may be applicable only to children with symptoms of allergic disease or they may also be helpful in children at risk of developing atopic disease. One might expect that in allergic families the parents themselves introduce primary prevention measures to reduce HDM exposure for their young children, even before the appearance of clinical signs of allergic disease. However, it is not clear whether or not this practice should be encouraged [12].

The aim of this study, as part of the Aalst Allergy Study, was to document bedroom conditions and to evaluate whether sleeping environment was associated with sensitization and allergic symptoms in an unselected population of Belgian children aged between 3.4 and 14.8 years.

Materials and Methods

Study Population

The study was performed from January 2004 to June 2005 in an unselected sample of children aged 3.4 to 14.8 years (mean age, 9.3 years) attending randomly selected nursery, primary, and secondary schools in the city of Aalst and the surrounding area. Aalst is a Flemish-speaking Belgian municipality situated 19 miles northwest of Brussels. It has a total population of 76 852 for a total area of 78.12 km^2, giving a population density of 983.83 inhabitants/km^2.

The parents of all 2674 children in the 2nd grade of nursery school, the 1st, 3rd, and 5th grade of primary school, and the 1st grade of secondary school were contacted, provided with a questionnaire, and invited to participate in the study. The parents of 2021 children (75%) returned a completed questionnaire and provided written consent for skin prick testing to be performed in their child.

Questionnaire

Parental questionnaires were distributed through the school doctors of the participating schools. The questions addressing respiratory and allergic disorders—ie, rhinoconjunctivitis, asthma, and eczema—were adapted from the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire [1] and also covered the items of the Brief Pediatric Asthma Screen Plus (BPAS+) score [13] (the scoring for the asthma component of the BPAS+ is a positive response to any of the following 4 items: wheeze, persistent cough, night cough, and response to change in air temperature). The questionnaire also included questions about demographic characteristics (age, gender, nationality, and maternal and paternal profession), exposure to tobacco smoke (prenatal and postnatal), and other potential risk factors for sensitization, such as premature birth, feeding practices in the neonatal period, family history of allergy, number of siblings, frequency of childhood infections, vaccinations, place of residence (urban or rural), animal contacts, and housing characteristics (age of building, heating, dampness, etc).

Detailed information on present bedroom conditions was gathered to address the following categories: floor surface, presence of stuffed toys, and bedding material. Smooth floors, such as parquet, tiles, seamless vinyl, and linoleum floor coverings were taken together in 1 category as they can be cleaned easily and thoroughly, while fitted carpet and wooden floors, considered as breeding grounds for HDM, were placed in another category. The presence of stuffed toys in the bedroom was categorized in 3 groups: no stuffed toys, 1 to 5 stuffed toys, and more than 5 stuffed toys. Finally, a distinction was made between washable bedding materials stuffed with Dacron or other synthetic materials and bedding materials stuffed with feathers or down.

Skin Prick Tests

Skin prick testing with the most common aeroallergens was performed by the same 2 trained pediatricians to ensure uniformity in testing technique and interpretation. The allergen panel consisted of *Dermatophagoides pteronyssinus*, *Alternaria tenuis*, cat, dog, mixed grass pollens, tree pollens, and *Blatella germanica* (cockroach); allergen extracts were used at a concentration of 100 index reactivity (IR) units per mL (Stallergenes, Waterloo, Belgium). Histamine solution (10 mg/mL in distilled water), was used as a positive control and saline as a negative control. Each child was tested on the volar surface of the forearm using 1-mm prick lancets (Stallergenes, Waterloo, Belgium). The skin reaction was recorded after 15 minutes by evaluating the skin response rate to inoculation of each allergen extract in comparison with the wheal given by the positive and the negative control. The size of each wheal was documented as the mean of the longest diameter and the diameter perpendicular to it. A positive test was defined as a mean wheal size, after subtraction of the negative control, of at least 3 mm, and a ratio of wheal size to allergen over wheal size to positive

Table 1. Baseline Characteristics of the Study Population*

	Study Population (n = 2021)		
	Not Sensitized (n = 1538)	Sensitized (n = 483)	Odds Ratio (95%CI)
Age, y, mean ± SD	9.0 ± 2.8 (range, 3.4 – 14.8)	10.0 ± 2.6 (range, 3.9 – 14.0)	
Age, y			
3.4 – 6	301 (84.1%)	57 (15.9%)	1
6 – 8	239 (86%)	39 (14%)	0.86 (0.55 – 1.34)
8 – 10	240 (79.5%)	62 (20.5%)	1.36 (0.92 – 2.03)
10 – 12	468 (70.3%)	198 (29.7%)	2.23 (1.61 – 3.10)
12 – 14.8	290 (69.5%)	127 (30.5%)	2.31 (1.63 – 3.29)
Sex			
Boy	697 (70.4%)	293 (29.6%)	1
Girl	841 (81.6%)	190 (18.4%)	0.54 (0.44 – 0.66)
Current animal exposure	1038 (76.8%)	313 (23.2%)	0.89 (0.72 – 1.11)
Passive smoke exposure	676 (78.6%)	184 (21.4%)	0.78 (0.63 – 0.96)
Maternal smoking during pregnancy	239 (77.9%)	68 (22.1%)	0.89 (0.66 – 1.19)
Prematurity	101 (82.8%)	21 (17.2%)	0.64 (0.40 – 1.04)
Breastfeeding	637 (75.8%)	203 (24.2%)	1.02 (0.83 – 1.26)
Eczema	310 (66.8%)	154 (33.2%)	1.87 (1.49 – 2.35)
Respiratory symptoms			
Coughing	398 (72.2%)	153 (27.8%)	1.33 (1.07 – 1.67)
Viral-induced coughing	368 (73.5%)	133 (26.5%)	1.21 (0.96 – 1.53)
Noninfectious coughing	44 (60.3%)	29 (39.7%)	2.17 (1.34 – 3.52)
Wheezing	263 (64.1%)	147 (35.9%)	2.13 (1.68 – 2.69)
Dyspnea	156 (61.9%)	96 (38.1%)	2.20 (1.66 – 2.90)
Exercise-induced	109 (60.2%)	72 (39.8%)	2.29 (1.67 – 3.15)
Laughing-induced	38 (57.6%)	28 (42.4%)	2.44 (1.48 – 4.03)
Weather-induced	109 (62.6%)	65 (37.4%)	2.04 (1.47 – 2.82)
Positive BPAS+ for asthma symptoms	612 (71%)	250 (29%)	1.62 (1.32 – 1.99)
Rhinoconjunctivitis			
No rhinoconjunctivitis	1241 (83.2%)	251 (16.8%)	1
Conjunctivitis	28 (53.8%)	24 (46.2%)	4.24 (2.42 – 7.43)
Rhinitis	175 (66.8%)	87 (33.2%)	2.46 (1.84 – 3.29)
Rhinoconjunctivitis	45 (29.4%)	108 (70.6%)	11.87 (8.17 – 17.24)
Family history of allergy			
No allergy	502 (79.9%)	126 (20.1%)	1
Parental allergy only	362 (73.9%)	128 (26.1%)	1.41 (1.07 – 1.87)
Sibling allergy only	125 ((73.1%)	46 (26.9%)	1.47 (0.99 – 2.17)
Parental and sibling allergy	217 (68.9%)	98 (31.1%)	1.80 (1.32 – 2.45)
Bedroom conditions			
Stuffed toys			
No	93 (66.9%)	46 (33.1%)	1
1 – 5	603 (72.7%)	227 (27.3%)	0.76 (0.52 – 1.12)
> 5	756 (79.2%)	198 (20.8%)	0.53 (0.36 – 0.78)
Bedding material			
Synthetic	975 (73.6%)	349 (26.4%)	1
Duvet or nonsynthetic bedding material	428 (80.6%)	103 (19.4%)	0.67 (0.53 – 0.86)
Floor			
Wood or fitted carpet	1299 (75.7%)	416 (24.3%)	1
Other	192 (80.3%)	47 (19.7%)	0.76 (0.55 – 1.07)

*Data are shown as number (%) unless otherwise indicated.
CI indicates confidence interval; BPAS+, Brief Pediatric Asthma Screen Plus.

Table 2. Influence of Stuffed Toys in the Bedroom on Sensitization and Allergic Symptoms*

	Skin Prick Tests		Respiratory Symptoms					
	At Least 1 Positive Test		Wheezing		Dyspnea		Noninfectious Cough	
	Numbers	OR_{adj} (95% CI)	Numbers	OR_{adj} (95% CI)	Numbers	OR_{adj} (95% CI)	Numbers	OR_{adj} (95% CI)
Total Study Group (n = 2021)								
No stuffed toys (n = 139)	N 93 (66.9%) P 46 (33.1%)	1	N 89 (67.9%) P 42 (32.1%)	1	N 104 (77.6%) P 30 (22.4%)	1	N 127 (92.7%) P 10 (7.3%)	1
Stuffed toys (n = 1784)	N 1359 (76.2%) P 425 (23.8%)	0.76 (0.52 – 1.11)	N 1387 (79.6%) P 355 (20.4%)	0.64 (0.43 – 0.95)†	N 1529 (87.9%) P 211 (12.1%)	0.57 (0.36 – 0.88)†	N 1707 (96.6%) P 60 (3.4%)	0.45 (0.22 – 0.89)†
1 – 5 (n = 830)	N 603 (72.7%) P 227 (27.3%)	0.84 (0.57 – 1.25)	N 626 (77.4%) P 183 (22.6%)	0.68 (0.45 – 1.02)	N 683 (84.6%) P 124 (15.4%)	0.68 (0.44 – 1.08)	N 787 (96.2%) P 31 (3.8%)	0.5 (0.24 – 1.05)
> 5 (n = 954)	N 756 (79.2%) P 198 (20.8%)	0.67 (0.45 – 0.99)†	N 761 (81.6%) P 172 (18.4%)	0.59 (0.39 – 0.89)†	N 846 (90.7%) P 87 (9.3%)	0.43 (0.27 – 0.69)†	N 920 (96.9%) P 29 (3.1%)	0.4 (0.19 – 0.84)†
Positive Family History for Allergy (n = 951)								
No stuffed toys (n = 64)	N 37 (57.8%) P 27 (42.2%)	1	N 35 (57.4 %) P 26 (42.6%)	1	N 45 (71.4%) P 18 (28.6%)	1	N 55 (87.3%) P 8 (12.7%)	1
Stuffed toys (n = 868)	N 630 (72.6%) P 238 (27.4%)	0.48 (0.36 – 0.65)†	N 631 (73.9%) P 223 (26.1%)	0.56 (0.33 – 0.96)†	N 712 (84%) P 136 (16%)	0.59 (0.33 – 1.06)	N 827 (96.1%) P 34 (3.9%)	0.28 (0.13 – 0.64)†
1 – 5 (n = 402)	N 266 (66.2%) P 136 (33.8%)	0.79 (0.46 – 1.35)	N 277 (70.1%) P 118 (29.9%)	0.63 (0.36 – 1.09)	N 313 (79.6%) P 80 (20.4%)	0.71 (0.39 – 1.31)	N 379 (95.5%) P 18 (4.5%)	0.33 (0.14 – 0.79)†
> 5 (n = 466)	N 364 (78.1%) P 102 (21.9%)	0.49 (0.28 – 0.86)†	N 354 (77.1%) P 105 (22.9%)	0.49 (0.28 – 0.87)†	N 399 (87.7%) P 56 (12.3%)	0.45 (0.24 – 0.85)†	N 448 (96.6%) P 16 (3.4%)	0.25 (0.1 – 0.60)†
Negative Family History for Allergy (n = 628)								
No stuffed toys (n = 41)	N 31 (75.6%) P 10 (24.4%)	1	N 33 (84.6%) P 6 (15.4%)	1	N 36 (90%) P 4 (10%)	1	N 39 (95.1%) P 2 (4.9%)	1
Stuffed toys (n = 563)	N 451 (80.1%) P 112 (19.9%)	1.26 (0.53 – 2.99)	N 480 (87.3%) P 70 (12.7%)	0.80 (0.29 – 2.15)	N 517 (93.2%) P 38 (6.8%)	0.67 (0.22 – 2.00)	N 543 (96.8%) P 18 (3.2%)	1.01 (0.12 – 8.84)
1 – 5 (n = 240)	N 183 (76.3%) P 57 (23.8%)	1.36 (0.56 – 3.30)	N 199 (85.4%) P 34 (14.6%)	0.99 (0.35 – 2.81)	N 212 (90.2%) P 23 (9.8%)	1.11 (0.35 – 3.45)	N 229 (96.2%) P 9 (3.8%)	1.21 (0.13 – 11.73)
> 5 (n = 323)	N 268 (83%) P 55 (17%)	1.15 (0.46 – 2.84)	N 281 (88.6%) P 36 (11.4%)	0.68 (0.24 – 1.91)	N 305 (95.3%) P 15 (4.7%)	0.41 (0.13 – 1.34)	N 314 (97.2%) P 9 (2.8%)	0.87 (0.09 – 8.26)

Table 2 (continued)

	Respiratory Symptoms									
	Sport Complaints		Triggered by Laughing		Triggered by Weather		Conjunctivitis		Positive BPAS+	
	Numbers	O_{Radj} (95% CI)	Numbers	OR_{adj} (95% CI)	Numbers	OR_{adj} (95% CI)	Numbers	OR_{adj} (95% CI)	Numbers	OR_{adj} (95% CI)
Total Study Group (n = 2021)										
No stuffed toys (n = 139)	N 106 (76.3%) P 33 (23.7%)	1	N 129 (93.5%) P 9 (6.5%)	1	N 115 (83.3%) P 23 (16.7%)	1	N 116 (85.3%) P 20 (14.7%)	1	N 65 (46.8%) P 74 (53.2%)	1
Stuffed toys (n = 1784)	N 1616 (92.1%) P 139 (7.9%)	0.28 (0.18 – 0.42)†	N 1689 (96.9%) P 54 (3.1%)	0.46 (0.22 – 0.95)†	N 1601 (91.7%) P 144 (8.3%)	0.44 (0.25 – 0.67)†	N 1561 (89.5%) P 183 (10.5%)	0.68 (0.41 – 1.12)	N 1042 (58.4%) P 742 (41.6%)	0.59 (0.41 – 0.85)†
1 – 5 (n = 830)	N 746 (91.2%) P 72 (8.8%)	0.31 (0.20 – 0.49)†	N 781 (96.4%) P 29 (3.6%)	0.53 (0.25 – 1.15)	N 730 (90.1%) P 80 (9.9%)	0.50 (0.30 – 0.84)†	N 714 (87.8%) P 99 (12.2%)	0.80 (0.48 – 1.35)	N 477 (57.2%) P 353 (42.5%)	0.61 (0.42 – 0.89)†
> 5 (n = 954)	N 870 (92.8%) P 67 (7.2%)	0.25 (0.16 – 0.39)†	N 908 (97.3%) P 25 (2.7%)	0.40 (0.18 – 0.86)†	N 871 (93.2%) P 64 (6.8%)	0.33 (0.20 – 0.56)†	N 847 (91%) P 84 (9%)	0.58 (0.34 – 0.97)†	N 565 (59.2%) P 389 (40.8%)	0.57 (0.39 – 0.83)†
Positive Family History for Allergy (n = 951)										
No stuffed toys (n = 64)	N 45 (70.3%) P 19 (29.7%)	1	N 56 (88.9%) P 7 (11.1%)	1	N 47 (73.4%) P 17 (26.6%)	1	N 48 (76.2%) P 15 (23.8%)	1	N 23 (35.9%) P 41 (64.1%)	1
Stuffed toys (n = 868)	N 766 (89.6%) P 89 (10.4%)	0.28 (0.15 – 0.49)†	N 816 (96%) P 34 (4%)	0.33 (0.14 – 0.79)†	N 764 (89.9%) P 86 (10.1%)	0.31 (0.17 – 0.57)†	N 735 (86.2%) P 118 (13.8%)	0.51 (0.28 – 0.95)†	N 473 (54.5%) P 395 (45.5%)	0.51 (0.30 – 0.87)†
1 – 5 (n = 402)	N 349 (87.9%) P 48 (12.1%)	0.33 (0.18 – 0.60)†	N 377 (95.7%) P 17 (4.3%)	0.36 (0.14 – 0.91)†	N 346 (87.6%) P 49 (12.4%)	0.39 (0.21 – 0.74)†	N 328 (82.6%) P 69 17.4 %)	0.67 (0.36 – 1.27)	N 214 (53.2%) P 188 (46.8%)	0.52 (0.30 – 0.90)†
> 5 (n = 466)	N 417 (91%) P 41 (9%)	0.23 (0.13 – 0.44)†	N 439 (96.3%) P 17 (3.7%)	0.31 (0.12 – 0.78)†	N 418 (91.9%) P 37 (8.1%)	0.25 (0.13 – 0.47)†	N 407 (89.3%) P 49 (10.7%)	0.39 (0.20 – 0.74)†	N 259 (55.6%) P 207 (44.4%)	0.50 (0.29 – 0.87)†
Negative Family History for Allergy (n = 628)										
No stuffed toys (n = 41)	N 34 (82.9%) P 7 (17.1%)	1	N 40 (97.6%) P 1 (2.4%)	1	N 37 (90.2%) P 4 (9.8%)	1	N 38 (95%) P 2 (5%)	1	N 25 (61%) P 16 (39%)	1
Stuffed toys (n = 563)	N 531 (95%) P 28 (5%)	0.26 (0.10 – 0.63)†	N 540 (97.8%) P 12 (2.2%)	0.04 (0.001 – 2.40)	N 524 (94.4%) P 31 (5.6%)	0.41 (0.13 – 1.29)	N 521 (94.2%) P 32 (5.8 %)	1.33 (0.28 – 6.25)	N 370 (65.7 %) P 193 (34.3%)	0.75 (0.37 – 1.50)
1 – 5 (n = 240)	N 225 (93.8%) P 15 (6.3%)	0.32 (0.12 – 0.85)†	N 225 (96.2%) P 9 (3.8%)	0.08 (0.001 – 6.37)	N 219 (93.2%) P 16 (6.8%)	0.52 (0.16 – 1.74)	N 218 (92.4%) P 18 (7.6%)	1.74 (0.36 – 8.54)	N 157 (65.4%) P 83 (34.6%)	0.79 (0.38 – 1.63)
> 5 (n = 323)	N 306 (95.9%) P 13 (4.1%)	0.21 (0.08 – 0.55)†	N 315 (99.1%) P 3 (0.9%)	0.03 (0.0 – 1.84)	N 305 (95.3%) P 15 (4.7%)	0.32 (0.09 – 1.08)	N 303 (95.6%) P 14 (4.4%)	1.02 (0.20 – 5.07)	N 213 (65.9 %) P 110 (34.1%)	0.72 (0.35 – 1.47)

*Data are expressed as numbers (%) and adjusted odds ratio (95% confidence interval). Odds ratio was adjusted for all factors that changed the unadjusted value by more than 5% (breastfeeding, passive smoke exposure, maternal smoking during pregnancy, housing conditions, day care attendance, pets, respiratory symptoms, family history of atopy, personal history of eczema, asthma and rhinoconjunctivitis, number of siblings, chronological position of the child in the family, and month of skin prick testing).
OR_{adj} indicates adjusted odds ratio; CI, confidence interval; N, negative; P, positive; BPAS+, Brief Pediatric Asthma Screen Plus.
†$P < .05$

control of at least 0.4. Use of H1 antihistamines was suspended at least 7 days before skin prick testing. Atopy was defined as at least 1 positive skin test to any of the 7 allergens tested.

Statistical Analysis

Descriptive statistical analysis methods were used to study the distribution of all covariates between the sensitized and nonsensitized children. Logistic regression analysis was used to study the association between covariates and the outcome (sensitized or nonsensitized). In a univariate analysis, the association between each covariate and sensitization was studied. We then performed stepwise addition of all risk factors for sensitization into the model. Risk factors were included in the final model if they changed the estimate by more than 5%.

A *P* value of less than .05 was considered statistically significant. All analysis was performed using the statistical package SPSS for Windows version 13.0.

Results

Two thousand and twenty-one children (75% of all contacted children) were included in the study after returning a completed questionnaire and with permission of their parents for skin prick testing. Table 1 shows the baseline characteristics of the study population. Negative skin prick tests were obtained in 1538 (76%) of the children and 483 children (24%) had at least 1 positive skin prick test.

First, we analyzed whether different types of flooring in the bedroom, the presence of stuffed toys, or the use of synthetic versus nonsynthetic bedding materials were associated with overall sensitization and sensitization to individual allergens. We observed a reduced risk of overall sensitization for children having more than 5 stuffed toys in their bedroom (adjusted odds ratio [OR_{adj}], 0.67; 95% confidence interval [CI], 0.45 – 0.99) (Table 2) and for children with nonsynthetic bedding material (OR_{adj}, 0.72; 95% CI, 0.56 – 0.93) (Table 3).

Table 3. Influence of Bedding Material on Sensitization and Allergic Symptoms*

	Skin Prick Tests				Respiratory Symptoms	
	At Least 1 Positive Test		HDM		Wheezing	
	Numbers	OR_{adj} (95% CI)	Numbers	OR_{adj} (95% CI)	Numbers	OR_{adj} (95% CI)
Total Study Group (n = 2021)						
Synthetic (n = 1324)	N 975 (73.6%) P 349 (26.4%)	1	N 1107 (83.6%) P 217 (16.4%)	1	N 998 (77.3%) P 293 (22.7%)	1
Nonsynthetic (n = 531)	N 428 (80.6%) P 103 (19.4%)	0.72 (0.56 – 0.93)†	N 474 (89.3%) P 57 (10.7%)	0.66 (0.48 – 0.91)†	N 425 (82.4%) P 91 (17.6%)	0.73 (0.56 – 0.95)†
Positive Family History for Allergy (n = 951)						
Synthetic (n = 679)	N 472 (69.5%) P 207(30.5%)	1	N 550 (81%) P 129 (19%)	1	N 480 (72.1%) P 186 (27.9%)	1
Nonsynthetic (n = 222)	N 174 (78.4%) P 48 (21.6%)	0.63 (0.44 – 0.90)†	N 198 (89.2%) P 24 (10.8%)	0.52 (0.33 – 0.82)†	N 167 (76.3%) P 52 (23.7%)	0.80 (0.56 – 1.15)
Negative Family History for Allergy (n = 628)						
Synthetic (n = 394)	N 310 (78.7%) P 84 (21.3%)	1	N 343 (87.1%) P 51 (12.9%)	1	N 330 (85.7%) P 55 (14.3%)	1
Nonsynthetic (n = 191)	N 156 (81.7%) P 35 (18.3%)	0.93 (0.59 – 1.46)	N 171 (89.5%) P 20 (10.5%)	0.93 (0.53 – 1.65)	N 166 (89.2%) P 20 (10.8%)	0.72 (0.42 – 1.25)

*Data are expressed as numbers (%) and adjusted odds ratio (95% confidence interval). The odds ratio was adjusted for all factors that changed the unadjusted value by more than 5 % (breastfeeding, passive smoke exposure, maternal smoking during pregnancy, housing conditions, day care attendance, pets, respiratory symptoms, family history of atopy, personal history of eczema, asthma and rhinoconjunctivitis, number of siblings, chronological position of the child in the family, and month of skin prick testing).
HDM indicates house dust mite; OR_{adj}, adjusted odds ratio; CI, confidence interval; N, negative; P, positive.
†$P < .05$

The type of flooring did not influence the prevalence of overall sensitization (data not shown). In terms of the individual allergens, a reduced risk of HDM sensitization was documented in children with nonsynthetic bedding material (OR_{adj}, 0.66; 95% CI, 0.48 – 0.91) (Table 3), while no association was found for the other individual allergens analyzed.

To study effect modification by family history of allergy, we stratified the results on the basis of a positive family history. We observed a protective effect of stuffed toys (Table 2) and nonsynthetic bedding material (Table 3) in children with a positive family history of allergy, whereas no association was found in children without a family history of allergy. We did not find statistically significant differences in the presence of stuffed toys between the subgroups of children with and without a positive family history of allergy ($P = .391$) but children with a positive family history of allergy used significantly more synthetic bedding materials than children without ($P = .001$).

In a second analysis, we studied the association between bedroom conditions and the presence of allergic symptoms. The self-reported allergic symptoms included respiratory symptoms (wheezing, dyspnea, chronic cough, and respiratory symptoms induced by exercise, laughing, or changes in weather conditions), eczema, and rhinoconjunctivitis. The presence of stuffed toys in the bedroom was associated with a lower prevalence of conjunctivitis and allergic respiratory symptoms. This effect remained significant after adjustment for possible confounders (Table 2) and increased with increasing number of stuffed toys. No statistically significant effect of the presence of stuffed toys on the prevalence of eczema or allergic rhinitis was observed (data not shown). Children with nonsynthetic bedding materials also reported fewer episodes of wheezing (Table 3), but no effect was observed for the other analyzed respiratory symptoms. The type of bedding materials was not associated with the presence of eczema or rhinoconjunctivitis.

After stratification for a positive family history of allergy, the association between the presence of stuffed toys or nonsynthetic bedding material and allergic symptoms was predominantly maintained in children with a positive family history of allergy (Table 2), while the association was no longer present in the group of children with a negative family history of allergy (Table 3).

The type of flooring used in the bedroom was not associated with differences in the prevalence of allergic symptoms in our study population (data not shown).

Discussion

In our study, the presence of stuffed toys and nonsynthetic bedding material in the bedroom were significantly associated with a lower prevalence of sensitization and some allergic symptoms (respiratory symptoms and conjunctivitis). In contrast, we found no protective effect of stuffed toys or nonsynthetic bedding materials on allergic rhinitis and eczema, and no association could be observed between the flooring and any of the analyzed variables.

The protective effect of bedroom exposure to stuffed toys and nonsynthetic bedding material could encompass several factors. Stuffed toys and nonsynthetic bedding materials can be considered not only as reservoirs of HDM but also as a reservoir of microbes and endotoxins. Several studies have demonstrated a higher degree of sensitization (especially with exposure in infancy and early childhood) [14,15] or more allergic symptoms in individuals who are exposed to higher levels of allergens such as HDM [16-18]. In contrast, the presence of microbes and endotoxins may be responsible for a lower prevalence of atopy and atopic symptoms, as stated in the hygiene hypothesis [8] and reported previously [19,20].

Similar to some other studies on pet ownership [21,22], the protective effect of stuffed toys and nonsynthetic bedding material was significantly more pronounced in children with a positive family history of allergy. This might be explained by genetic predisposition as a fundamental factor governing susceptibility to atopic disease. However the protective effect of pet ownership in the first months of life is also disputed, since recent data suggest that this effect might be determined by pet removal in those families with a history of allergy [12,23].

The observational nature of this study means that our data should be interpreted with caution. First of all, since this was a cross-sectional study, risk factors and outcome (sensitization and allergic symptoms) were measured at the same time. As a result, the chronological order of exposure and manifestation of allergic sensitization cannot be distinguished. In addition, information on risk factors was retrieved from the completed parental questionnaires and no dust collections or other measurements in the children's bedrooms were undertaken.

Several steps were taken to avoid or document potential biases or confounders. Children were only eligible to participate in the study if their parents consented to the use of skin prick tests and completed the questionnaire. One could imagine that selection bias might have occurred as parents of children with a positive family history of allergy might be more likely to agree to participate. However selection bias is probably not substantial in this study, as our prevalence rates for sensitization are in line with other published data [1,24] and our response rate was rather high (75%).

One might expect atopic families to be sensitive to the presence of triggering factors such as bedroom conditions. If this information bias were present, one would expect the atopic families to have reported fewer stuffed toys and greater use of smooth flooring. However, we did not observe a significant difference between atopic and nonatopic families ($P = .391$ and $P = .108$, respectively).

Finally, we should also be aware of the potential for a positive family history of allergy to act as a confounder. One could well imagine that atopic families are more aware of triggering factors for sensitization than nonatopic families. This would imply that parents with a positive family history of allergy already took preventive measures such as reducing the number of stuffed toys and using synthetic bedding material. This might have been true in our study population for the use of synthetic bedding materials. However, we did not find statistically significant differences in the presence of stuffed toys between the subgroups of children with and without a positive family history of allergy. Although the results for the whole study group were corrected for a positive family history

of allergy, there might be the potential for residual confounding factors, as we have no data on the levels of mite allergens and endotoxins in the bedroom environment, nor information on the frequency of washing of the bedding material and stuffed toys. It is likely that families with a history of allergy wash those items more frequently than do nonallergic families, and that could lead to a lower degree of exposure to mite allergens and consequently a reduced risk for allergic sensitization. Thus, large prospective follow-up studies are needed to elucidate the effect of these complex interactions and to confirm the results of the present study.

In conclusion, HDM avoidance is generally accepted to be one of the basic approaches to management of HDM allergy and includes measures such as removal of stuffed toys, duvets, and carpeting from the bedroom. This may lead to the introduction of such measures in the prevention of allergy in children with a positive family history for allergy. However, our data suggest a possible protective effect of bedroom exposure to stuffed toys and nonsynthetic bedding materials on sensitization and development of allergic symptoms in genetically predisposed children. Although the evidence from our study is compelling, in order to be able to give appropriate preventive advice to parents our data need to be confirmed by prospective studies involving measurement of levels of mite allergens and endotoxins and assessment of the time, degree, and duration of the exposure.

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References

1. Worldwide variation in prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and atopic eczema: ISAAC. The International Study of Asthma and Allergies in Childhood (ISAAC) Steering Committee. Lancet. 1998;351:1225-32.
2. Isolauri E, Huurre A, Salminen S, Impivaara O. The allergy epidemic extends beyond the past few decades. Clin Exp Allergy. 2004;34:1007-10.
3. von Mutius E, Weiland SK, Fritzsch C, Duhme H, Keil U. Increasing prevalence of hay fever and atopy among children in Leipzig, East Germany. Lancet. 1998;351:862-6.
4. Strachan DP. Hay fever, hygiene, and household size. BMJ. 1989;299:1259-60.
5. Kemp A, Bjorksten B. Immune deviation and the hygiene hypothesis: a review of the epidemiological evidence. Pediatr Allergy Immunol. 2003;14:74-80.
6. Romagnani S. The increased prevalence of allergy and the hygiene hypothesis: missing immune deviation, reduced immune suppression, or both? Immunology. 2004;112:352-63.
7. Romagnani S. Immunologic influences on allergy and the TH1/TH2 balance. J Allergy Clin Immunol. 2004;113:395-400.
8. Bloomfield SF, Stanwell-Smith R, Crevel RW, Pickup J. Too clean, or not too clean: the Hygiene Hypothesis and home hygiene. Clin Exp Allergy. 2006;36:402-25.
9. Sidenius KE, Hallas TE, Brygge T, Poulsen LK, Mosbech H. House dust mites and their allergens at selected locations in the homes of house dust mite-allergic patients. Clin Exp Allergy. 2002;32:1299-304.
10. Eggleston PA. Methods and effectiveness of indoor environmental control. Ann Allergy Asthma Immunol. 2001;87:44-7.
11. Ricci G, Patrizi A, Specchia F, Menna L, Bottau P, D'Angelo V, Masi M. Effect of house dust mite avoidance measures in children with atopic dermatitis. Br J Dermatol. 2000;143:379-84.
12. Custovic A, Simpson BM, Simpson A, Kissen P, Woodcock A. Effect of environmental manipulation in pregnancy and early life on respiratory symptoms and atopy during first year of life: a randomised trial. Lancet. 2001;358:188-93.
13. Wolf RL, Berry CA, Quinn K. Development and validation of a brief pediatric screen for asthma and allergies among children. Ann Allergy Asthma Immunol. 2003;90:500-7.
14. Custovic A, Simpson BM, Simpson A, Hallam CL, Marolia H, Walsh D, Campbell J, Woodcock A. Current mite, cat, and dog allergen exposure, pet ownership, and sensitization to inhalant allergens in adults. J Allergy Clin Immunol. 2003;111:402-7.
15. Huss K, Adkinson NF, Jr., Eggleston PA, Dawson C, Van Natta ML, Hamilton RG. House dust mite and cockroach exposure are strong risk factors for positive allergy skin test responses in the Childhood Asthma Management Program. J Allergy Clin Immunol. 2001;107:48-54.
16. Wahn U, Bergmann R, Kulig M, Forster J, Bauer CP. The natural course of sensitisation and atopic disease in infancy and childhood. Pediatr Allergy Immunol. 1997;8:16-20.
17. Kuehr J, Frischer T, Meinert R, Barth R, Forster J, Schraub S, Urbanek R, Karmaus W. Mite allergen exposure is a risk for the incidence of specific sensitization. J Allergy Clin Immunol. 1994;94:44-52.
18. Lau S, Illi S, Sommerfeld C, Niggemann B, Bergmann R, von Mutius E, Wahn U. Early exposure to house-dust mite and cat allergens and development of childhood asthma: a cohort study. Multicentre Allergy Study Group. Lancet. 2000;356:1392-7.
19. Gehring U, Bischof W, Fahlbusch B, Wichmann HE, Heinrich J. House dust endotoxin and allergic sensitization in children. Am J Respir Crit Care Med. 2002;166:939-44.
20. Niven R. The endotoxin paradigm: a note of caution. Clin Exp Allergy. 2003;33:273-6.
21. Roost HP, Kunzli N, Schindler C, Jarvis D, Chinn S, Perruchoud AP, Ackermann-Liebrich U, Burney P, Wuthrich B. Role of current and childhood exposure to cat and atopic sensitization. European Community Respiratory Health Survey. J Allergy Clin Immunol. 1999;104:941-7.
22. Braback L, Kjellman NI, Sandin A, Bjorksten B. Atopy among schoolchildren in northern and southern Sweden in relation to pet ownership and early life events. Pediatr Allergy Immunol. 2001;12:4-10.
23. Svanes C, Zock JP, Anto J, Dharmage S, Norback D, Wjst M,

Heinrich J, Jarvis D, de Marco R, Plana E, Raherison C, Sunyer J. Do asthma and allergy influence subsequent pet keeping? An analysis of childhood and adulthood. J Allergy Clin Immunol. 2006;118:691-8.

24. Heinzerling L, Frew AJ, Bindslev-Jensen C, Bonini S, Bousquet J, Bresciani M, Carlsen KH, van Cauwenberge P, Darsow U, Fokkens WJ, Haahtela T, van Hoecke H, Jessberger B, Kowalski ML, Kopp T, Lahoz CN, Lodrup Carlsen KC, Papadopoulos NG, Ring J, Schmid-Grendelmeier P, Vignola AM, Wohrl S, Zuberbier T. Standard skin prick testing and sensitization to inhalant allergens across Europe--a survey from the GALEN network. Allergy. 2005;60:1287-300.

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